130K-1

METALWORKING: HOT & COLD

AG 130-K

UNIT OBJECTIVE

After completion of this unit, students will be able to identify common metals, understand and show safe use of metal working tools, and project layout and construction. This knowledge will be demonstrated by completion of assignments and a unit test with a minimum of 85 percent accuracy.

SPECIFIC OBJECTIVES AND COMPETENCIES

After completion of this unit, the student should be able to:

1. Identify samples of cast iron, mild steel and aluminum.
2. Identify ten common metalworking tools by type and use.
3. Lay out a drawing on metal for project construction.
4. Make square and circular bends in metal, using an anvil or vise.
5. Determine tap drill sizes for specific applications
6. Use files and saw blades correctly.
7. Join metal by riveting. (Supplemental)
8. Cut threads with a tap and die.
9. Layout and drill holes with a twist drill.
10. Operate power tools such as drills and saws after completing appropriate safety tests.

130K-2

METALWORKING SAFETY

A. Safety Practices for Working Cold Metal

When working cold metal, observe the following safety practices. When performing cold metalwork, you should know and observe the general as well as the specific safety practices for the hand tools power tools, and portable power tools used.

1. Keep the work area clean. Wipe up oil and grease spills immediately to prevent injuries caused by slipping and falling. Keep paths to exits clear.
2. Use eye protection. When doing cold metalwork, wear approved safety glasses or a face shield.
3. Store rags safely. Store oily and greasy rags in a fireproof metal container to prevent the spreading of spontaneous fires.
4. Use the correct lifting method. Serious injury may result from straining due to incorrect lifting. Lift heavy objects with the leg muscles, not the back muscles. When lifting heavy objects, obtain assistance.
5. Use proper tools. Always use the proper-sized tools and equipment for the job.
6. Obtain the instructor's permission. Use equipment only with the instructor's permission. Notify the instructor immediately if you are injured.
7. Wear proper clothing. Wear clothing that is not loose or bulky and wear hard-toed shoes with non-skid soles.
8. Ground electrical equipment. Each electrical tool should be equipped with a three-prong plug and plugged into a grounded three-hole receptacle. When used outside, portable tools should be connected to ground fault circuit interrupter outlets.
9. Restrain long hair. Restrain excessively long hair with a band or cap to keep hair from getting entangled in machines. When using a drill or drill press, be extremely careful with long hair.
10. Secure stock. Be certain that stock to be cut, filed, or chiseled is securely fastened in a vise or by clamps to prevent tools from slipping.
11. Mount holding devices securely. Mount vises, anvils, and clamps securely for cold metalwork.

B. Safety Practices for Using Hand Tools in Cold Metalwork

Before studying the specific safety practices for using hand tools, review the cold metalwork general safety practices.

1. Provide handles for files. Handles on files reduce the possibility of a puncture wound from the file tang.
2. Clean files properly. Use a file card to remove metal from a file. Never use your hands.
3. Never use a file for prying. Excessive pressure on the file while you are prying may cause it to break.
4. Avoid tools with mushroomed heads. Small particles of metal from the mushroomed heads of punches or cold chisels may break off and cause injury.
5. Keep cutting-edge tools sharp. Dull chisels are dangerous as they require excessive pressure and hammering to make them cut.
6. Cut away from bystanders. To avoid hitting bystanders with flying chips, chip and cut in the opposite direction.
7. Carry sharp tools properly. All sharp-edged tools and chisels should be carried with the cutting edge down. Never carry sharp tools in a pocket.
8. Avoid hammers with loose heads. A loose hammerhead is dangerous as it may fly off during use and cause injury.
9. Use the correct hammer for the job. Never use a carpenter's hammer to strike punches or chisels.
10. Watch your fingers. Take special care when you are hammering so that you strike the object, not your fingers.
11. Use a wrench of the proper size. Wrenches that fit improperly may slip and cause injury. Adjust wrenches to fit snugly on a nut to avoid slipping.
12. Pull on wrenches-do not push. Pushing on a wrench is dangerous because the nut may break loose unexpectedly, thus causing skinned or cut knuckles. Always pull with the force on the stationary side of an adjustable wrench.
13. Never extend handles. Handles that are extended with a pipe may break unexpectedly and thus cause injury.
14. Never strike wrenches with hammers. Striking a wrench with a hammer may cause the wrench to bend or break.
15. Use pliers properly. Use pliers for their intended purposes only. Never use pliers in place of a wrench.
16. Do not use damaged wrenches. Because wrenches with badly worn, chewed, or spread opening are likely to slip, they should not be used.
17. Never throw tools. Never toss tools to another worker. The tools may be damaged or the worker may be injured.
18. Keep tools clean. Keep tools and hands clean and free of grease and oil so that you can grip tools properly.
19. Store tools properly. Never leave tools where they may fall, be stepped on, or bumped into. Store tools in a safe location to prevent injury to others and to prevent tools from being damaged.

C. Safety Practices for Using Metal-cutting Band Saws and Power Hack Saws*

Before studying the specific safety practices for using metal-cutting band saws and power hack saws, study the stationary power tools general safety practices.

1. Secure metal in the saw vice. Slipping metal can cause blade breakage and injury.
2. Clean chips from saw properly. Use a brush to clean metal chips from the saw. Never use your hand! Do not attempt to clean the saw while it is running.
3. Handle cut metal carefully. Newly cut pieces of metal containing burrs can cause serious cuts. When handling metal with burrs, wear gloves. Remove burrs from metal as soon as possible.
4. Support long stock. To prevent long pieces of metal from falling, always use a stand to support long stock.
5. Use proper holding devices. Secure irregularly shaped objects in a holding device, such as a V-block for round stock and a drill vise for small objects.
6. Always start a new blade in a new kerf. Because of the set in the new saw blade, the kerf is wider than the kerf made by a used blade. Starting a new saw in an old kerf will ruin the set and may break the blade.

D. Safety Practices for Using Drill Presses*

1. Wear industrial-quality eye protection. Wear safety glasses which are approved and meet the Z87.1 standards.
2. Use good-quality bits. For the safest and most efficient operation, use only straight, sharp, burr, and nick-free bits.
3. Tighten the bit securely in the drill chuck. Use a chuck wrench to tighten the bit in the chuck. Be certain to remove the chuck wrench after the bit has been tightened.
4. Anchor the drill press. An unanchored drill press is unstable and easily turned over.
5. Use proper holding devices. Secure irregularly shaped objects in a holding device, such as a V-block for round stock and a drill vise for small objects.
6. Use a cleaning brush. Remove chips with a brush, not your hands. Cuttings are sharp, and splinters or cuts could result.
7. Avoid seizing. Relieve pressure on the drill just before it breaks through the stock to prevent it from binding, causing the stock to rotate or the drill bit to break.
8. Support the ends of long stock. This will keep undue pressure from being exerted on the drill.

9. Never attempt to stop revolving stock with your hands! Do not attempt to stop a revolving piece of stock in which the drill is caught. Cut off the power and then free the bit.
10. Remove the bit from the chuck. After the drilling is completed, remove the bit from the chuck and then place it in its designated place.
11. Attach the vise permanently. Attach the vise to the drill table in such a way that it is permanent but pivatable.
12. When using the drill press, do not wear baggy clothes or leave long hair loose.

SAFETY IN HOT METALWORK

A. Safety Practices for Working Hot Metal

Observe the following general safety practices for working hot metal.

1. Obtain the instructor's permission. Before using any tool or machine, you must obtain the instructor's permission. The instructor must be aware of all laboratory activities and will know if the equipment is in safe working order.
2. Wear industrial-quality eye protection. To protect the eyes from sparks and metal chips, wear approved eye protection.
3. Wear proper clothing. To protect against burns, wear clothing such as coveralls, high-top shoes, leather aprons, and leather gloves. Remove all paper from pockets, and wear cuffless pants.
4. Protect hair and scalp. To protect the hair and scalp, restrain excessively long hair and wear a cap.
5. Know emergency procedures. In the event of an emergency, all students involved in or observing the emergency should call for help immediately as well as assist in correcting the situation. You should know the location of fire extinguishers and fire blankets and how to use them. You should also know the approved procedure for exiting the laboratory.
6. Report all injuries. Report all injuries or accidents to the instructor immediately, no matter how slight. The instructor will secure medical help.
7. Keep work area and tools clean. Dirty, greasy, and oily tools and floors can cause accidents. Clean and put away all unneeded tools and materials. Clean up oil spills and scrap metal from the floor and equipment.
8. Use correct tools. Always use the right size tool and only for its intended purpose. Use tongs or pliers for carrying hot metal.

9. Avoid horseplay and loud talk. Loud talking as well as pushing, running, and scuffling while working with hot metal can cause serious accidents. Keep your mind on your work.
10. Work in a well-ventilated area. Fumes and intense heat are part of hot metalwork and require that work be done outdoors or in a forced-ventilated area. This is especially true when you are working with zinc (galvanized iron or pipe), cadmium, or beryllium.
11. Use correct lifting methods. When lifting heavy objects, obtain help. Lift with the legs and not the back. Straining to lift heavy objects can cause serious injury.
12. Store hot metal in a safe place. To avoid the possibility of accidental burns, keep hot metal in a safe place until it cools. Do not offer hot stock to the instructor for inspection.
13. Never touch suspected hot metal. Test metal with moistened finger tips before actually touching it. Use tongs or pliers for handling hot metal.
14. Turn off heat source before leaving work area. Before leaving the laboratory or workstation, make certain the heat source is shut off and cool.
15. Avoid using hot metalwork around flammable material. Do not perform hot metalwork on wood floors or near flammable material. Never work on containers that have been used for storage of combustible material without first having cleaned and safeguarded them.
16. Protect welder cables and hoses when you are hot metalworking. Keep cables and hoses from coming in contact with hot metal and sharp objects. Never point a flame at cables or hoses.
17. Use warm water instead of quenching oil for quenching. Quenching oil is easily confused with other oils. It is difficult to identify. If quenching oil is used, take it from new, previously unopened cans.

B. Safety Practices for Using a Gas Furnace*

Before studying the specific safety practices for using a gas furnace, review the hot metalwork general safety practices.

1. Check for leaking gas. Before firing the furnace, check all the connections with soapy water for possible leaks. This will prevent a possible fire or explosion.
2. Light the furnace correctly. When firing the furnace, keep the doors open and stand to one side. Otherwise ignition may cause the doors to fly open.
3. Use tongs. When removing metal from a hot furnace, always use tongs that fit the stock.

4. Use a safeguard system. A gas furnace should, equipped with a safeguard system such as the ultra-violet combustion safeguard system.
5. Use a flint lighter. When lighting a manually ignited gas furnace, always use a flint lighter. Never use matches.

C. Safety Practices for Using an Electric Furnace*

Before studying the specific safety practices for using an electric furnace, review the hot metalwork general safety practices.

1. Avoid electrical shock. Be certain the furnace is grounded and that the electric lead cable is properly insulated.
2. Check grating for scale. Before using the electric furnace, make sure there is no scale on the grating. Scale can short and burn out the coils.
3. Keep the door closed. When the furnace is not in use or is left unattended, make certain that the door is closed.
4. Use tongs. When removing hot metal from the furnace, always use tongs that fit the stock.

SAFETY IN SOLDERING, BRAZING, AND SHEET METALWORK

Before studying the specific safety practices for soldering, brazing, and sheet metalwork, review the hot metalwork general safety practices.

A. Safety Practices for Using a 14-Oz. Propane Torch

1. Wear industrial-quality safety glasses. Wear safety glasses to protect your eyes from spatter and fumes.
2. Use a flint lighter-not matches-to light the propane torch. Matches will bring your fingers too close to the flame.
3. Keep the propane tip pointed away from your body.
4. While using propane torches or cylinders, do not smoke or allow others to smoke because of the potential fire hazard.
5. Turn the propane nozzle off properly. Close the propane tank valve snugly, but do not overtighten. Because the propane tank valve is made of copper, excess pressure will strip the threads. The nozzle should be turned off when there is no flame to prevent propane from escaping and filling the work area with gas.
6. Attach the propane nozzle correctly. Screw on the nozzle tightly to avoid leakage and possible explosion.
7. Remove the propane nozzle from the canister when finished. When you are finished for the day, remove the nozzle from the canister to prevent any gas from escaping.

8. Do not refill propane canisters. Only trained persons should refill canisters. The contents are under pressure and could explode.
9. Dispose of empty propane canisters properly. Do not incinerate empty canisters because they will explode.

B. Safety Practice for Using Electric Soldering Irons

1. Handle the soldering iron carefully. To prevent burns and fire, handle the electric soldering iron with care.
2. Inspect soldering iron cords and plugs regularly. Always inspect the cord of an electric soldering iron for poor insulation before you use it. Unplug the cord when you are finished or interrupted.
3. Do not lay down a hot soldering iron on wood, paint solvents, or other combustible materials.
4. Never solder in a damp area. Stand on a dry board when you are soldering if the floor or ground is damp or wet.
5. Store soldering iron safely. Allow copper to cool before you store the iron.

SAFETY PRACTICES FOR USING A COAL FORGE AND AN ANVIL

Before studying the specific safety practices for using a coal forge and an anvil, review the hot metalwork general safety practices.

1. Secure the anvil. Be certain the anvil is securely anchored so that it will not give under pressure and fall.
2. Keep the anvil's face clean. Keep the face of the anvil dry and free of scale.
3. Strike the anvil properly. Never strike the face of the anvil with a hammer or another object that is as hard as the anvil.
4. Cut metal safely. When cutting hot metal on an anvil, use a handled hot metal cutter and the cutting block or hardy.
5. Protect others. When working with metal on an anvil, warn observers and bystanders to keep back, as metal chips may fly.
6. Keep tools in good condition. Keep forge tools sharp and free of mushroomed heads. Be certain that handles are tight in forge hammers.
7. Use correct tongs. When handling hot metal, always use tongs that fit the stock.

ACTIVITY:

1. Draw a floor plan of the shop indicating the power tool positions, bench locations, and doors; show all safety equipment located in the shop.
2. Develop a list of shop tools used in metalworking for a home shop. Price the tools from the local hardware store or a catalog.

IDENTIFICATION AND USE OF BASIC METALWORKING TOOLS

A. Identification and Use of Metalworking Tools

1. Scratch Awl (Scribe) - hardened steel rod with a sharpened point that enables user to make marks on metal.
2. Metal Snips - hand-held pliers-like tool used for cutting sheet metals. Jaws are non-gripping to allow easy release.
3. Ball-peen Hammer - a hammer consisting of two ends, the ball end and the face end. The ball end is used for shaping round edges such as rivet heads, while the face end is used for square work.
4. Hacksaw - hand-held saw with a replaceable blade. The blade should be attached with the teeth facing forward to allow for cutting on the downstroke (forestroke) only. The hacksaw is used for cutting all types of thin metals such as round stock, pipes, tubing, and bar stock.
5. File - a hand-held piece of hardened steel of various shapes and sizes. Files have a heel end which contains the handle and a point end. They are designed to be held at both ends and moved lengthwise over the work.
6. Electric Powered Hand Drill - a hand-held drill motor capable of holding a drill bit. The hand drill is used to drill holes in work that otherwise cannot be carried to a drill press.
7. Drill Press - a mounted drill used for precision drilling of smaller portable objects. The desired location for a hole is marked and center punched. Holes is drilled at appropriate diameter and depth.
8. Taps and Dies - hardened steel tools used to make inside and outside threads. Taps are designed for inner threads or nuts and other holes. Dies are made for outside threads on bolts and other round stock. A hole is pre-drilled for the proper the size tap. Round stock is beveled prior using the die.
9. Pedestal Grinders (bench grinder) - consists of electric motor and spinning stone. Work can be carried to grinder and manipulated for desired outcome.

10. Electric Soldering Iron - consists of a handle and soldering lead. Used for waterproofing corners of sheet metal projects by applying quick hardening solder.

ACTIVITY:

1. Have students demonstrate the proper and safe use of each of the ten tools listed above.
2. Design a project which utilizes at least five of the tools mentioned in this lesson.

TYPES AND PROPERTIES OF COMMON METALWORKING MATERIALS

A. Sheet metal is thin gauge metal used to form ducting, boxes, and machine guards by bending, folding, and otherwise manipulating.

1. Types of Sheet Metal Commonly Used in Agricultural Mechanics

a. Galvanized or zinc-coated mild steel is the most common type used in the industry. It is available in thickness gauges from 16 ga. to 28 ga. Galvanized mild steel sheet metal is commonly used to build tool boxes, planter boxes, brooders, and anything else requiring durable yet thin metal sheets.
b. Uncoated mild steel sheet is also available in 16 ga. to 28 ga. This sheet can be used for fence-siding, and other projects which will ultimately be painted.
c. Copper and brass sheet is often used to do decorative sheet metal work such as name plates and signs.
d. Aluminum sheet metal, available in different alloys, is also used in decorative applications. It does not rust or corrode easily but is brittle and may crack when worked improperly. In addition to the fastening techniques listed below, aluminum sheet can be welded with a MIG type welder.

2. Material Fasteners Used with Sheet metal

a. Rivets are used to great advantage with all sheet metal work. Normally the rivet should be the same material as the metal.

1) Size the rivet to fit the rivet hole very close.
2) The rivet should extend 1 1/2 diameters through the sheet metal, then riveted over to form head and hold metal together.

b. Blind rivets or "pop rivets" are also used in hard-to-get-at places. These are available in steel, stainless steel, and aluminum.
c. Sheet metal screws provide the ability to easily take the pieces apart and then put them back together. Using a sharp punch to make a hole instead of punching or drilling the pilot hole for the screw provides more material for the metal screw to "bite" into and improves the holding strength.
d. Machine screws and stove bolts also provide a secure joint and will support more weight than a sheet metal screw. They are also used to attach sheet metal to wood or heavier metal.

B. Metalworking Terms

1. Terms

a. Strength refers to the ability of a metal to hold loads without breaking. Steel is strong, but lead is weak.
b. Hardness of a metal refer to its ability to resist penetration, wear, or cutting action.
c. Malleability refers to its ability of metal to be rolled, forged, hammered, or drawn without cracking or breaking. Gold is the most malleable metal.
d. Ductility refers to the ability of a metal to be stretched without breaking. Baling wire is very ductile.
e. Coldwork - Most of the metalwork done in drilling, taping, bending, and forming is done without heat. As metal is worked cold it becomes harder and will tend to crack if done too much. This is called, work hardening.
f. Heat Treatment - Any heating and controlled cooling process that is designed to produce special properties of hardness, softness, or alteration of the strength of a metal.
g. Tempering - a metal hardening process done by controlled heating and controlled cooling; it is done to relieve stress in the metal.

C. Iron

1. Types of Iron Commonly Used in Agricultural Mechanics

a. Cast Iron - coarse-grained steel with a 2-6% carbon content. It is brittle and therefore best used under compression pressure rather than tension. Types of cast iron include gray and white. Cast iron is commonly used for machine parts and hydrants.

D. Carbon Steel

1. Carbon steels are iron which contain a specified percentage of elemental carbon.

    a. Low carbon steel (mild steel) - contains .05 to .30 percent carbon. Its soft, tough, and malleable characteristics make it suitable for rivets, screws, nails, and low strength machine parts. Used in bar, square, and flat stock it is the most common steel used for a variety of repairs and projects around the agricultural mechanics shop.
    b. Medium carbon steel - contains .30 to .70 percent carbon. It is used to make bolts, axles, hammers, and screwdrivers.

E. Shapes and Sizes of Steel

1. Mild steel is available in the form of bar, square, and flat stock. This type of stock is measured by its thickness and width. Common lengths are 8 and 16 feet.
2. Sheet steel is available by thickness (gauge) and, as the name implies, is sold in sheets. 4 feet by 8 feet is common.
3. Angle iron, channel iron and "I" beams are forms of mild steel that are measured by thickness, width and-web (internal dimension) size. This form of mild steel is commonly used in agriculture to make frames for equipment and machinery.
4. Round tubing and pipe are commonly used in agriculture for irrigation, fence posts, and transport of fuels. Tubing is generally smaller and is measured by outside diameter (OD) and wall thickness. It is more commonly used in fuel lines and low pressure, low flow water systems. Pipe is generally larger and is measured by inside diameter (ID) and wall thickness. Pipe is used in irrigation as well as fence and building construction.
5. Square tubing is measured by wall thickness and outside dimensions. Square tubing is used for construction of gates and light-duty frames such as bench tops.

F. Aluminum

1. Alloys of aluminum - consist of aluminum plus the addition of small quantities of other metals (copper, silicon, manganese, and others) normally less than 7% or 7% added metal to obtain specific alloys.

a. Cast alloys are the basic aluminum material which cast parts are made of by heating to its melting point and pouring in a mold.

b. Wrought alloys are derived from cast alloy but heated to a specific temperature and then formed by rolling, forging, and/or extruding through a die.

ACTIVITY:

1. Examine samples of different metals of various sizes and shapes, and use technically correct terms to describe them.

LAYOUT AND TRANSFER

A. Planning - An important step in beginning any project is thinking it out. A drawing can assist the thought process.

1. Layout Tools - Both measuring and layout tools require skill in use and care in handling and storage. Provide clean and dry work areas and storage cabinets to house tools. Wipe all metal tools with a lightly oiled rag to protect their finish. Steel wool can return rusted metal tools to usable condition.

a. A steel rule is used in making linear measurements, checking straight lines, and projecting straight lines onto metal. A steel rule's normally marked in units down to 1/32."
b. A scribe is used to scratch the surface of metal when marking or projecting lines. Keep the end sharp with emery cloth.
c. A combination square set is a very versatile tool for checking the project squareness, centering on a circle or pipe, and developing any angle down to 1 degree by using the protractor head.
d. A spring divider is used to transfer a dimension or measurement from the rule to the metal. It can also be used to scratch circles or arcs in the metal.
e. An awl or a prick punch is used to transfer directly from drawing to sheet metal by placing the drawing on top of the metal and then tapping the awl with the palm of the hand to mark the metal through the drawing.
f. A center punch is used to enlarge a mark for a drill to follow in order to prevent wandering of the drill bit.
g. A steel pencil with soft, grey, special lead allows the metalworker to mark for rough measurements to about 1/16" accuracy. This mark is easily seen and will work on the oil coated surface of most steels.

h. Soapstone is a white, soft, natural element cut to either a rectangular or round shape about 4" long and used to mark rough measurements on steels for rough cutting.
i. A combination bevel is a transfer tool used to copy different angles from a blueprint onto metal.

2. Measurement - The first step in correct layout is to measure with exact dimensions the item being copied using a rule, tape measure, dividers, and compass.

a. The ability to read and measure correctly both whole and fractional dimensions from rule to work and back to the rule requires concentration and counting accurately along the rule.
b. Practice exercises in drawing lines of specific length (for example, 1 3/16," 5/32," 2 1/8") are recommended before layouts are done on metal.
c. Practice in measuring and recording pre-drawn lines and listing the correct number and fraction measured is also recommended as a skill building activity.

B. Layout or transfer work is the placement of the measurements and lines or outlines on the metal. It is done in full scale and allows for saw cuts or kerf as needed. The measurements are usually taken off the drawing when laying out, but they may be measured directly from a project being copied or duplicated.

C. Layout of a Project for Construction

1. Using the measurement tools previously discussed, determine the proper length and angles required for the project.
2. Transfer the dimensions from blueprint to metal using one of several methods discussed above.

a. Attach a drawing (full size) of the project to the metal. Using a scratch awl, make an outline of the project on the metal.
b. Transfer lines from a blueprint to metal using a straight edge and soapstone or chalk. Be sure all lines are straight and angles are correct.
c. Use templates or cardboard, etc., to transfer curves and angles.

ACTIVITY:

1. Draw a paper layout of a parts box and then cut it out and fold it into its finished shape.
2. Measure an object like a simple box and then transfer the measurements to a paper layout drawing in full scale. When the layout is complete, including the dimensions, transfer the drawing to the metal, using a scratch awl.

SHEETMETALWORKING

A. Sheet metal Tools

1. Cutting Sheet metal

a. A cold chisel is used with a hammer and a vise to shear the metal when only the piece in the vise is to be saved.
b. Tin snips are available in several sizes and jaw shapes; they are used to cut metal as thick as 20 gauge by hand.
c. A hand notcher removes a small notch from the edge of a piece of metal in order to allow the metal to be bent in a circle to the inside or to the outside.
d. A hand punch is a 'C'-clamp shaped tool which uses an inside punch and outside die to cut holes in sheet metal. The size can quickly be changed to the desired diameter.
e. Aircraft shears or compound snips come in right hand cut, left hand cut, and straight cut depending upon the shape being cut. They make use of compound leverage action for easy cutting and have a slightly serrated cutting edge to grip the metal.
f. A squaring shear is a foot operated cutting shear which will cut a full width sheet of metal in one cut. It is used to make long cuts and produce smaller pieces for use as projects.

2. Bending and Folding Tools

a. A setting hammer is a small 6-8 oz. hammer with a square-shaped face on the head and a sloped or slanted peening end used to close sheet metal down around a wire.
b. A tinner's bench plate and stakes consists of a large, heavy plate of cast steel with a series of square holes that accept many different kinds of shaping stakes used in bending and forming sheet metal.

c. A hand seamer is a pliers-like tool with long, flat, smooth jaws that grip the sheet metal in order to fold it over or partially bend it.
d. A hand crimper shortens one side of an angle in order to allow it to be curved to the inside.
e. A sheet metal brake is a hand- or foot-operated bending machine that is wide enough to allow large pieces of sheet metal to be bent at one time along a single line. It can usually bend up to 120 degree angles.
f. A sheet metal roll former is a hand-operated machine that uses three rollers to bend the metal around itself to form a tube, a ring, or a curved metal piece.

B. Sheet metal Layout

1. Project Selection

a. Select a simple project such as a small tray or box.
b. Include in the project seams, hems, tabs, holes, folds (bends), and notches.
c. Use a thin gauge metal to make the project (24-26 gauge).
d. Draw the project on paper, then cut out and fold the paper template before doing the project in metal.
e. When the paper template is correct, place the template over the sheet metal and tape it down. Using the awl, prick a small indentation through the template and into the metal at each intersecting point of lines. This forms a "dot-to-dot" on the metal which can then be connected with the scriber to form the outline and bend lines of the project.
f. Finish the project by soldering all the tab joints so they are watertight when tested.

C. Cold Metal Riveting

1. Riveting can be done with or without heat. Cold metal riveting is used with small rivets and/or small riveting jobs. The process is as follows:

a. Mark, center punch and drill a hole slightly larger than the diameter of the rivet.
b. Load the rivet into a pliers-type pop-riveter being sure that the rivet is tightly held.
c. Place the free end of the rivet through a pre-drilled hole and squeeze the handle of the pop-riveter. (It normally requires two (2) squeezes of the handle to properly set the rivet.)

d. The rivet can be flattened by placing the project on an anvil and striking it with a ball peen hammer.

2. Soldering Process

a. Cleaning - Since soldering is an alloying process, the base metals must be very clean in order for the solder to adhere to the surface of the metal.

1) Pre-clean with steel wool, wire brush, or emery cloth.
2) Use a 50% solution of muriatic acid and water in order to remove grease, wax and metal oxides from the base metal. (Caution: Eye protection and other safety procedures should be followed when soldering or preparing to solder.)
3) Acid and/or rosin flux are used during soldering for the following reasons:

a) They remove any final oxides of the base metal just before soldering.
b) They prevent or minimize oxidation while the base metal is being heated.
c) They aid in the flow of heat to the base metal and protect the solder from oxidation while it is molten.

4) Note: Wash sheet metal with water when finished soldering in order to remove any traces of acid or flux and to prevent metal corrosion.

b. The base metal pieces must be heated to just above the melting point of the solder and kept at this temperature while the soldering is being done.

1) A light coat of solder is sometimes applied to the surface of the metal and rubbed along with steel wool to tin the surface before going back and completely soldering the joint.
2) Several sources of heat may be used to solder:

a) Blowtorch and soldering copper
b) Electric soldering iron
c) Propane hand torch bottle

d) Electric soldering gun (usually used for small work)

3) Heat evenly and feed the solder into the metal at the point of application of the heat. (The molten solder will seek the heat and capillary action will draw the solder into the joint.)

ACTIVITY:

1. Practice cutting, drilling, and bending sheet metal.
2. Practice cold riveting on sheet metal.
3. Design and build a simple sheet metal project such as bookends or a coal scoop.

COLD METALWORK

A. Working metal cold is an easy and economical method of forming metal into various projects in a short time. Cold metalwork is the process of hand bending, drilling, taping, and cutting soft steels. It is one of the major types of manufacturing used to produce livestock and farm machinery (and equipment.

B. Metalworking

1. Tools Used to Cut Cold Metal

a. A hacksaw is a stiff-backed, bow-type saw with a replaceable metal cutting blade. There are from 16 to 32 teeth per inch.
b. A cold chisel is used with a hammer to cut through bolts and round stock or to cut sheet metal. Cold chisels come in various sizes.
c. A bolt cutter is a large-jawed cutting tool which can be used to cut round steel rods and soft bolts or small-square shaped steel bars.

2. Bending Metal Cold

a. Vise - The standard shop vise with 3" to 5" size jaws works very well to secure and hold light steel to hand bend or form the metal to shape. Bending can also be done by allowing the jaws of the vise to remain open and use the pivots to bend gentle curves in strap steel and rod or pipe.

b. Adjustable Open-end Wrench - A Crescent wrench is a suitable leverage device to cold bend the lighter steel shapes. A short length of pipe or a large hammer can also be used.

c. To make a square bend: Clamp metal in the vise so the point of the bend is flush with the top of the vise jaw. Using a ball peen hammer or a rubber mallet, bend the metal by lightly striking just above the vise jaws (point of bend). Check for proper bend (90 degrees) using a square.

d. Circular bends may be accomplished in one of several ways.

1) Fashion a jig out of 2 short pieces of pipe (size will be determined by desired degree of bend) and a flat piece of iron. Weld the pipe onto the iron at the desired distance. The jig can then be clamped into the vise. The metal can be placed between the jig pipes and manipulated for the desired bend. This procedure works best with strap steel and rod.
2) Bend shallow curves by manipulating the metal around the open jaw of the vise.

4. Filing Metal

a. Files are used to remove small amounts of metal and to shape and smooth the surface. A file card should also be available to clean the file as needed.

b. File Shapes - The shape of the file selected depends on the amount of contact surface to be filed or grooved.

1) Round - Round files come in different diameters and have a slight taper to the length of the file. It is not like a chainsaw sharpening file which is straight.
2) Flat - flat files come in many different cuts:

a) rough cut	d) second cut
b) coarse	e) smooth
c) bastard	f) dead smooth

3) A triangular file has three cutting sides and a narrow face.
4) A half round file has one flat face and one rounded face.
5) A knife file has two flat faces which come together as a sharp side or knife edge along one side.

c. Safe Use of Files

1) Files should be cleaned with a file card whenever necessary.
2) All files should have a handle in order to prevent injuries to the hands.
3) Files should be held by both the front end and the handle. Hold the front end between the tips of the fingers and the thumb. Allow the file handle to rest in the palm of the hand.
4) Push the file forward with light yet steady pressure. Draw back with light yet steady pressure. Repeat steps as necessary.

5. Drilling Metal

a. Punch mark a good center point before drilling. Go deep enough to allow the drill to center up on the mark.
b. Twist drills come in three common sets or index groups and also a metric index.

1) Fractional Index - twist drill sizes from 1/16" diameter to 1/2" diameter by 64ths of an inch.
2) Lettered Index - twist drills from letter size 'A' to 'Z'; the letter 'A' is small and the letter 'Z' is big.
3) Numbered Index - twist drills from number 1 to number 60; number 1 is medium while number 60 is very small.
4) Metric Sizes - change by one millimeter per drill size.

c. Drilling Procedure (drill press, portable electric hand drill)

1) Punch mark for a good center.
2) Select the correct size drill for the job.
3) Consult a drill speed chart to determine what RPM the drill should be operated (1/2" drill = 458 RPM). Change the drill press drive to the correct speed.
4) Chuck the drill securely into the drill press and check to see that the drill spins true.
5) Use a good quality cutting oil to lubricate and cool the drill while it is being used.
6) Use safety goggles when drilling with the drill press.
7) Drill with an even down pressure, but still allowing the drill to cut through the metal instead of being punched through. Relax the down pressure just before the drill breaks through the opposite side.

6. Taping Threads in Metal (threading the inside of a hole)

a. Thread Sizes - All machine screw and bolt threads are straight cut threads which means that the first thread cut and the last thread cut are the same depth. The number of threads per inch varies depending upon the strength and torque required for the job and the size of the screw or bolt.

b. Thread Pitch - This is the term given to the angle that the threads make to the head of the bolt. A coarse pitch will not hold as well as a fine pitch. These are usually referred to as national coarse and national fine thread bolts.

1) example: 1/4" diameter X 20 tpi National Coarse
2) example: 1/4" diameter X 28 tpi National Fine

c. Selecting a Tap Drill - The tap drill is the correct size twist drill used to pilot just the right size hole through the metal to be followed by the selected tap.

1) A tap size chart with corresponding tap drill size is listed below:

NATIONAL COARSE THREAD CHART

Size Thread	Threads/inch	Tap Drill Size
1/4"	20	#7 (13/64" approx.)
5/16"	18	#F (1/4" approx.)
3/8"	16	5/16"
7/16"	14	#U(23/64" approx.)
1/2"	13	27/64"
9/16"	12	31/64"
5/8"	11	17/32"
3/4"	10	21/32"

NATIONAL FINE THREAD CHART

1/4"	28	#3 (7/32" approx.)
5/16"	24	#I (17/64" approx.)
3/8"	24	#Q (21/64" approx.)
7/16"	20	25/64"
1/2"	20	29/64"
9/16"	18	33/64"
5/8"	18	37/64"
3/4"	16	1 1/16"

7. Using a Tap

a. Taps vary by thread cut as well as the shape of the tap. There are three types of taps:

1) Taper Tap - This has a long, slender, easy starting entry into threading cutters, but must be allowed to tap entirely through the metal piece in order to cut all threads to the specified depth.
2) Plug Tap - This has a medium entry into the metal and can also be used to start the thread, but should continue the threading all the way through the metal.
3) Bottoming Tap - This tap does not start threads very well but will cut the thread all the way to the bottom of a blind hole which will then accept a bolt almost all the way to the bottom.

b. Starting the tap in the metal straight and keeping it straight is the most difficult part of this job. Work slowly and align the vertical axis of the tap perpendicular to the surface of metal being tapped. Use a gentle but firm down pressure on the tap handle.
c. Turn the tap several turns to get a good bite on the metal. Then as the tap is turned into the metal each half to full turn, back the tap up enough to break off the metal chip being cut (about one fourth turn).
d. Be sure to clean all threading material out of the threads before they are used to twist in a bolt or screw.

8. Using a Die

a. Putting threads on the outside of a rod to form a bolt is done using a die and die stock or handle.
b. The dies also cut standard threads in National Coarse and National Fine sizes to match the taps discussed previously.
c. Cutting threads involves most of the same procedures used in tapping threads with these additional hints:

1) Select the correct die thread size to go with the tap threads used or with a nut already selected. Set the alignment marks on the die cutters to be just across from one another. This will cut a standard clearance thread fit between the inside and outside threads.

2) Grind the tip of the rod to be threaded with a slightly chamfered end in order to allow the die to easily start straight.
3) Start the die with an even down pressure and hold the die stock level so the threads start an even cut.
4) Turn the die clockwise for one half to one full turn and then back off one fourth turn to clear the chips from the die.
5) When the threads have been cut as long as required, back the die off the threads and clean on a wire brush.

9. Using Power Tools for Cold Metalwork

a. Power Hacksaw - This is a band-type saw designed to cut all metal angle, bar, strap, channel, pipe, and other shapes of construction steel. This saw is easy to operate.

1) Clamp the work firmly in the vise of the saw, at the desired cutting angle, in such a way that the most teeth of the blade will come in contact with the work when cutting begins.
2) Turn on the saw and lower the blade until it begins to cut and then set the balanced cutting weight of the saw to work.
3) The automatic shut-off of the saw should stop the saw when the piece has been cut through.

b. Power Drill Press - A drill press can be either a floor model or a shorter bench model; both operate equally well.

1) When using a drill press always use a drill press vise to secure the work and assure a quality drilling job.
2) First select the correct drilling speed from the chart provided with the drill press. The speed (RPM) depends on the size of the drill; generally, the larger the drill size the slower the speed.
3) Place the drill bit in the chuck and tighten it using the chuck key. Then check to see that it spins true before turning on the drill press.
4) Check next to see if the drill is located and centered on the center punch mark already placed in the work.

5) Start drilling slowly to check the center alignment and then place a small amount of cutting oil in the hole and continue to drill with even pressure. Apply more cutting oil as the drilling progresses.
6) When close to finishing, relax the down pressure in order to go through the opposite side slowly.

ACTIVITY:

1. Select a tap drill for several different tap sizes.
2. Lay out several cuts and hole centers on a piece of steel and then cut, drill, and tap the material.

HOT METALWORK

A. Using heat to help soften metal and then using controlled cooling for hardness and stress relief have been done by blacksmiths for many years.

1. Welding was originally done by heating two pieces of metal to a red hot temperature and then hammering the two together on an anvil.
2. Cutting, punching, upsetting (shortening), drawing out (lengthening) are all hot metal procedures used by the blacksmith.

B. Hot Metalworking Tools

1. Types of Forges

a. Permanent natural gas fired forges are good for heavy metal work and inexpensive to operate. (The original forges used coal.)
b. A portable propane fired forge is the best forge for most school shop use because it stores easily and provides ample heat.
c. The chimney of the forge is used in order to get a good draft. Ample ventilation must be used with a forge and fire precautions must be taken when using this high heat source.

2. Anvils and Bases

a. Anvils are made and purchased by weight. A good size for a shop anvil is 150 pounds. (Some portable anvils are only 60 pounds and other anvils are made for special purposes) such as horseshoeing.
b. The anvil base must be of a solid but absorbent material. The best base is made of a large round of oak or other hard wood cut to allow the height of the face of the anvil to be touching the knuckles of a fist when standing by the anvil with the hand held down. Concrete can also be used and is preferred by some.

3. Other Equipment Needed

a. Blacksmith's ball peen hand hammer, 1 lb., 10 oz.
b. Machinist's hammer, 1 lb., 8 oz.
c. Blacksmith's cross peen sledge, 10 lb.
d. Machinist's vise
e. Hardie to fit anvil, used to cut metal when hot
f. Hot cut chisels
g. Tongs, straight-lipped, 1/4" opening, 18" length
h. Tongs, bolt, 3/8" to 1/2," 18" length
i. Water bucket or quenching tank

C. Hot Metalwork Procedure

1. Holding the Stock - Because burns are a potential problem with hot metalwork, the correct method of holding the metal is very important.

a. Select tongs that fit the work.
b. Keep the tongs cool by dipping them in water.

2. Measuring Stock - Use chalk to measure the stock. Use a center punch or file to mark the exact point to be heated.

a. For a curved piece of metal, use a light piece of wire to form a shape template and then straighten the wire and measure its length.
b. To make a ring, the amount of metal needed is three and a half times the diameter of the ring plus half the diameter of the stock.

3. Heating the Stock - Caution must be used when heating metal in order to avoid having the metal reach a "white heat" stage where it will oxidize or burn.

a. Heat should be evenly applied to the entire area to be worked.
b. For welding operations, bring like pieces to the same temperature together.
c. Determine what amount of heat is necessary to do the job and use no more heat than is needed.

4. Annealing is the heating and slow cooling of metal done in order to soften it and remove stress.

a. To anneal iron and steel, heat the stock slowly to a uniform red color and bury the stock in air-slack lime, pulverized charcoal, or wood ashes.
b. Remove the metal only after it has completely cooled.

5. Tempering - The hardeness and brittleness of steel for certain purposes is controlled by how it is heated and cooled. Tools such as chisels, hammers, picks, and shears are tempered to last a longer time or maintain their cutting edge.

NOTE: Not all steels can be tempered successfully. Use a high quality tool steel for best results.

a. To temper, heat the piece of metal to a cherry red color. (Never heat tool steel to higher than a bright red or a low-orange heat or it becomes coarse-grained and weak.)
b. Dip the end to be tempered into water while moving it up and down slightly in order to cool the tip rapidly (this will harden the tip).
c. Remove the tip from the water while the other part of the metal is still red hot; this allows the heat to creep back into the cooled end.
d. Brighten the cooled end immediately with a file and watch for the colors to move back into the cooled end. (See color chart below.)
e. When the desired color has just reached the cooled end, immediately plunge the end back into the water and stir the water as before.
f. Finally, when the piece has returned to a black color it may be totally submerged in the water for complete cooling.

6. Tempering Color Chart: (Chart shows hardest first.)

a. Project:

1) Lathe Cutting Tools Hammers	Light Straw Color
2) Punches Taps and Dies Drills Reamers Knives	Dark Straw Color
3) Axes Shears	Dark Brown Color
4) Cold Chisels Center Punches Rivet Sets	Purple Color
5) Screwdrivers Springs Gears Picks Saws	Blue Color

7. Bending and Shaping with Heat

a. Heating large pieces of metal that are to be bent allows the metal to work easier and make a sharper bend.
b. Correct heating and bending will retain the strength of the metal while it is worked. Never over-heat the metal. Normal heating temperature is reached at a dull cherry red color.
c. When using a hammer to form the bend, hit blows hard but as few times as possible in order to prevent a coarse grain from forming as the steel cools.
d. Never continue to bend or shape when the color has left the steel. Hammer only when the metal is still red hot.
e. Twisting stock can also be done with heat and should follow the same procedures as above.

8. Cutting Metal Hot

a. Hot metal may be cut with a hammer and hardie on the anvil as well as with a hot chisel.
b. To cut the metal, heat it to a cherry red color and lay it across the hardie at the point it is to be cut. (The hardie goes into the Hardie hole in the anvil.)
c. Hit the metal piece with the hammer directly over the hardie and slowly rotate the piece so a groove forms at the point of the cut. When the groove goes entirely around it, hold the piece at the edge of the anvil and strike a sharp blow to break off the excess.
d. Lighter stock can be cut directly over the hardie simply by hammering through it.

9. Drawing Out

a. Lengthening or slimming a piece of metal is termed drawing out. It is done in the following way:

1) Heat the stock to a white heat.
2) Place the stock on the anvil and use a hammer to strike slight glancing blows. Have the hammer glance off in the direction the stock is to be lengthened.
3) While hammering, turn the stock slightly so it will be hammered evenly on all sides.
4) To change the stock from a square cross section piece to a round cross section piece, first hammer the square to an octagon and then round the corners of the octagon to a round shape.
5) Hammer evenly on all sides and hold the piece at the correct angle to the face of the anvil so the piece will not be bent while it is being hammered.
6) Reheat the stock when it cools below a cherry red color. Do not hammer without color!

10. Upsetting

a. Shortening or thickening a piece of metal is termed upsetting. It is done in the following way:
b. Heat the part of the stock to be enlarged to a white heat.
c. Place the stock in a vertical position on the face of the anvil in order to prevent bending.

d. Strike the cold end of the work with hard blows from the hammer. If the piece bends, quickly place it flat on the anvil and hammer out the bend. Continue hammering until the desired shape is reached or the piece has cooled to a dull red heat. Do not hammer without color!

11. Riveting with Heat (an alternative to cold riveting)

a. Riveting can be done with or without heat but it is easier done with heat. The process is as follows:

1) Place the rivet into a hole just slightly larger than the diameter of the rivet.
2) With the two pieces of the work held firmly together, the rivet should stick out of the back side of the work by one and a half times the diameter of the rivet.
3) Place the work, with the rivet head down, on the top of the anvil or over a heavy piece of steel.
4) Heat the end of the rivet quickly with a torch or carbon arc to a dull cherry red color.
5) Immediately strike the rivet with a sharp, heavy blow to upset the metal and spread the end. Use a single flat blow which should be ample to size and fix the rivet in place.

ACTIVITY:

1. Heat metal to different colors and shape it using the anvil, hammer, hardie, tongs, and gloves.
2. Take a piece of tool steel 7" long, heat it, and form it into a cold chisel.

130K-30

Name_____
Date_____
Score_____

UNIT EXAM, METALWORKING

Multiple Choice, Answer the following questions with the most correct answer.

1._____ The thickness of sheetmetal is measured by _____.

a. tenths of an inch
b. hundredths of an inch
c. thousandths of an inch
d. gauge

2._____ Annealing means to

a. harden
b. soften
c. throw away
d. drill holes

3._____ A scribe is a tool used for _____.

a. measuring
b. drilling
c. squaring corners
d. drawing lines on metal

4._____ In hot metal work, upsetting means to _____.

a. shorten or thicken
b. heat and quench in water
c. heat and cool slowly
d. effects from distortion

5._____ When selecting a rivet for length, how long should the rivet head stick out beyond the back surface of the metal?

a. Same as the diameter of the rivet.
b. One and a half times the diameter of the rivet.
c. Twice the diameter of the rivet.
d. 1/4"

6._____ Which of the following is NOT a common type of sheetmetal material?

a. Aluminum
b. Mild steel
c. Stainless steel
d. Cast iron

7._____ In order to be considered cast iron the carbon content must be _____ percent.

a. 2 – 6
b. 8 – 12
c. 14 – 20
d. 20 – 25

8._____ A tap is used to make _____ threads.

a. male
b. female

9._____ A die is used to make _____ threads

a. male
b. female

10.____ Which of the following type is NOT a thread size?

a. Fine thread
b. Medium thread
c. Course thread
d. Machine thread

11.____ When riveting metal together you should use rivet made out of _____ material.

a. the same
b. stronger
c. softer
d. none of the above

12.____ When drilling metal always use a _____ to make the center of the hole.

a. cold chisel
b. chalk mark
c. center punch
d. pin punch

Short answer or fill in the blanks of the following questions.

13. The correct color for working metal hot when bending is _____.

14. The word that means the opposite of annealing is _____.

15. The correct color to indicate metal hardness if you want to make an ax or shear is _____.

16. List and describe the three different types of taps

1._____

2._____

3._____

17. Are the threads on a bolt and a pipe the same? (yes/no)

18. What makes up the galvanized coating in metal (sheetmetal or pipe)?_____

19. Ductility refers to the ability of metal to be _____ without breaking.

20. How many square inches are there in a 4 foot by 8 foot sheet of sheetmetal?

Answer Sheet, Exam

1. D
2. B
3. D
4. A
5. B
6. D
7. A
8. B
9. A
10. B
11. A
12. C
13. Red or light orange color
14. Tempering
15. Dark Brown Color
16. Taper Tap, Plug Tap, Bottoming Tap
17. No
18. Zinc
19. Stretched
20. 4,608 sq/in

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Special Materials and Equipment:

Scratch awls, metal snips, ball-peen hammers, hack saws, files, electric power hand drill, drill press, taps and dies, pedestal grinder, electric soldering iron. Graph paper, pencil, ruler, compass, small sheet metal piece, scribe. Layout tools, sheet metal working tools, two pieces of 24-28 gauge galvanized sheet metal for each student. Metalworking hand tools and power tools, a bench vise, various sizes of mild steel strap in different thicknesses from 1/4" to 1/2". A source of heat to heat and bend metal, preferably a gas fired forge; if not available, an oxyacetylene torch; blacksmith tongs, anvil. Select and have available for students ten common metalworking tools to see and handle. Provide several power tools for demonstration and student inspection also.

See Section 130Y for sheetmetal, hot and cold metal projects.